Design and Investigation of Hybrid Renewable Energy (HRE) Systems in Jordan, With the Goal of Bolstering the Agricultural Sector of the Country

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Abstract

This study investigates the feasibility of creating an agricultural community consisting of multiple housing units, with an agricultural plantation or plot of agricultural land for each dwelling. This community will be equipped with renewable energy sources such as wind and sun, which will reduce the relatively high cost of electricity, especially for agricultural uses such as water pumping. This study uses the HOMER Pro software to design hybrid renewable energy (HRE) systems for three agricultural locations in Jordan, where these places in Zarqa, Ma'an, and Mafraq Governorates. By determining the technical and economic parameters, including solar insolation, wind speed, energy demand, costs, and fuel prices, were analysed to evaluate system feasibility. The main results indicate that hybrid energy systems are both technically and economically feasible for agriculture in Jordan, offering lower costs of energy (COE) and reduced dependence on fossil fuels. Depending on HRE systems leads to enhancing the stability of the electrical grid, and ensuring the power supply during peak demand, which leads to improved electrical system efficiency. Thus, this search will result in encouraging land reclamation and making it agriculturally productive, as well as encouraging the return of citizens to their original homes and discouraging them from abandoning their lands and migrating to urban areas; This, in turn, will promote agriculture in Jordan.

Keywords

Renewable Energy, PV, Wind Energy, Jordan, HRES, HOMER

Introduction

Traditional energy resources such as oil, gas and coal are considered the primary source to supply the different activities with the needed energy. This energy consumption has increased gradually due to several reasons, such as the industrial sector's great development and the increasing demand that requires new framing techniques and transportation that demands a considerable amount of energy (Thomas, 2020; Wang & Li, 2016). This consumption behaviour leads to the need to discover new resources for energy to cover the enormous demand. Renewable energy resources are discussed to be the optimal solution for this challenge (Kuang, 2016). Different methods and tools for extracting energy from these resources have been developed at different levels, such as the amount of generated power, to be appropriate in different applications in industrial and residential fields.

Jordan is one of the countries that has different problems with traditional energy resources; for example, about 94% of Jordan's oil and gas are imported, in addition to the growth of energy demand, which is about 3% (Abu-Rumman, 2020). On the other hand, political issues in the Middle East have contributed to the increased energy demand, where Jordan is one of the countries hosting refugees from Syria (Lahn, 2016). For this investigation, efficient alternatives to the traditional energy resources are needed to reduce energy consumption in Jordan. Considering Jordan's climate and geographical location are the elementary factors for choosing suitable energy resources (Ammari, et al., 2015). Solar energy and wind energy were the best candidates to improve the produced energy by taking into account the energy quality, availability and reliability of the constructed power system (Jaber, 2015).

In terms of exploiting renewable energy resources in Jordan, different projects were developed and constructed to meet the increase in energy demand. Al Safawi, a solar PV project, was one of these projects; Al Safawi for Green Energy PSC constructed a 51 MW solar photovoltaic plant with a power capacity of about 51 MW. In this project, bout 201,000 panels were employed (Rahim & Eid, 2017). Another illustration of PV projects is the 60.3 MW Mafraq solar PV project; ACWA Power International developed this project to construct a solar PV plant in the Mafraq Development Area (Seznec, 2018). For wind energy projects, the 45 MW Shobak wind project was constructed for the National Electric Power Company (NEPCO) as a client, where this wind power plant involves 13 wind turbine generators (Hamzeh, 2020). These projects are typical

examples of projects that were developed to improve the sustainability feature of the power system in Jordan and to provide the power system with the needed energy demand.

In order to get the maximum advantage of solar energy and wind energy, crucial issues should be faced and solutions proposed to overcome these issues. The significant effect of these issues can make the renewable power system inefficient (Kiwan & Al-Gharibeh, 2020). Considering the PV solar plant structure, several problems should be taken into account, such as the amount of generated power having a high dependency on the weather, and the generated energy should be stored in a central storage unit, which is considered to be expensive (Brecl, 2018). On the other hand, the wind energy system also has its own problems that affect the power system, where the fluctuations of the wind speed affect the stability system in addition to the high costs of maintenance (Ahmed, et al., 2020).

A hybrid power system was found to be the optimal solution to overcome the different issues of both the solar and wind energy systems and take advantage of the positive points of both systems (Gao, et al., 2019). This paper has the object of designing a Hybrid Renewable Energy System (HRES) for generating electricity in Jordan. HRES has the feature of providing a stable and consistent power supply, considering that every energy source has its own energy profile. A combination of any two or more renewable energy resources is considered to be HRES, but the most common hybrid renewable energy system is the wind-solar energy system (Huang, et al., 2015). Such a system has the feature of being less expensive in terms of operating and maintenance costs.

Jordan has long been a farming powerhouse in the Middle East. The country's farmers produce some of the region's best dates, honey, and olives. But in recent years, they've had to contend with climate change. Droughts have become more frequent and intense, making it harder for farmers to water their crops. And as temperatures have risen, so have the rates of evaporation and evapotranspiration (the process by which water is lost through the leaves of plants) (Mukundi, 2021). In response to these challenges, Jordan's government has been investing in renewable energy sources like solar and wind power. These investments are not only helping the country meet its growing energy needs—they're also providing a boost to Jordan's agricultural sector. Solar and wind farms require large tracts of land, which are often leased from farmers. The lease payments provide a much-needed source of income for farmers, who can use the money to buy

better irrigation systems or invest in other improvements. The presence of solar and wind farms also provides another benefit: employment opportunities for Jordan's rural residents (Hamed & Lindsey, 2019).

The energy challenges in Jordan have affected different areas, not only in the energy sector, where the industry and agriculture will also be affected. The agriculture sector has encountered several issues due to the need for additional energy demand to improve agriculture ways and tools (Jebli & Youssef, 2017). The energy demands for agriculture can be divided into direct and indirect energy needs. The direct energy demand involves irrigation, harvesting, storage and transportation (Belda Gonzalez, 2018). The indirect energy needs can be considered to be fertilisers and insecticides, which have a great role in improving the food production processes. The proposed hybrid power system can provide the required demand for agriculture in Jordan and solve the energy problem in this sector.

2. Mathematical model

The behaviour of the hybrid system should be analysed by defining the general principle of work. This can be stated and developed by investigating the mathematical principles for both the wind turbine and the photovoltaic cell. These relations can provide the expected values for the generated power and the related quantities that can describe different factors that affect the work of the proposed design of the hybrid system.

2.1 The mathematical model of the PV module

The main idea of the PV module is to receive the falling sunlight and convert it into electricity. The PV module is basically consisting of several solar cells connected to each other in series, and a group of PV modules connected in series or parallel forms a PV array. The main component of the photovoltaic module is the P-N junction of the solar cell, which is composed of a semiconducting material such as Germanium or Silicon. According to the photovoltaic effect, electrons extract the required energy from the sunlight falling on the PV modules to overcome the band gap energy and flow in an external path, and the electricity will be produced because of that (Villalva, et al., 2009). The characteristics of the solar cell, which are the P-V and I-V proportional

to the received sunlight and the temperature of the PV module and have a nonlinear behaviour (Aly, et al., 2019).

The equivalent circuit of the solar cell and its three types, which are the ideal, simplified and practical models, are shown in Figure 1. In the ideal case, the value of the R_s and R_p will be zero because R_p represents the current leaking to the ground, and R_s represents the current flow based on internal losses

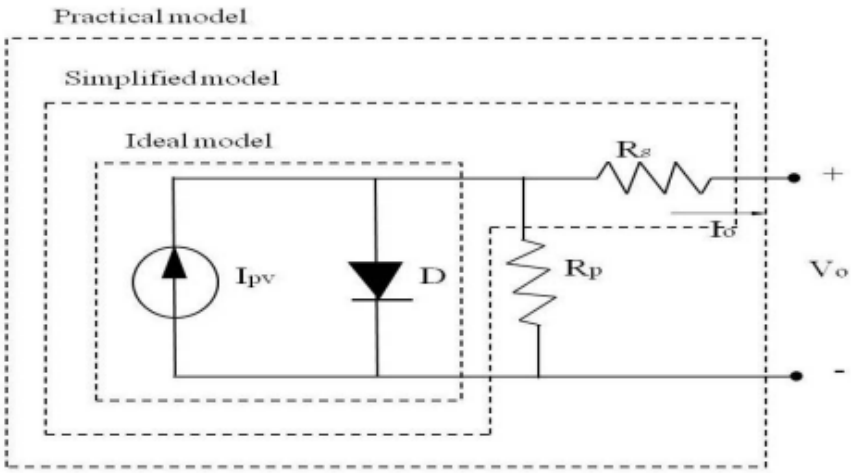

Figure 1: The equivalent circuit of the solar cell (Suthar, et al., 2013)

The output current produced by the PV module depends on two parameters, which are the saturation current of the diode (I_o) and the photo current (I_{pv}) as shown in the equation below (Babu, et al., 2015):

$$I = I_{pv} - I_o(e^{\frac{q(V+IR_S)}{KATN_S}} - 1) - \frac{V+IR_S}{R_p} \quad (1)$$

Where,
I_{pv}: Photo current of the solar cell
I_o: Saturation current of the diode
q: The charge of the electron $1.6*10^{-19}$
T: Temperature of the PV module in Kelvin
K: Boltzmann constant $1.38*10^{-23}$
A: Diode ideality constant
N_s: Number of the PV modules connected in series
R_s: Resistance connected in series
R_p: Shunt resistance
I: The output current of the PV module

To obtain the maximum possible power from the PV module according to the above equation, the best condition will be at IMPP and VMPP as shown in Figure 2, so that the equation of the maximum power will be as shown below (Hamdan, et al., 2019).

$$P_{max} = I_{MPP}V_{MPP} \quad (2)$$

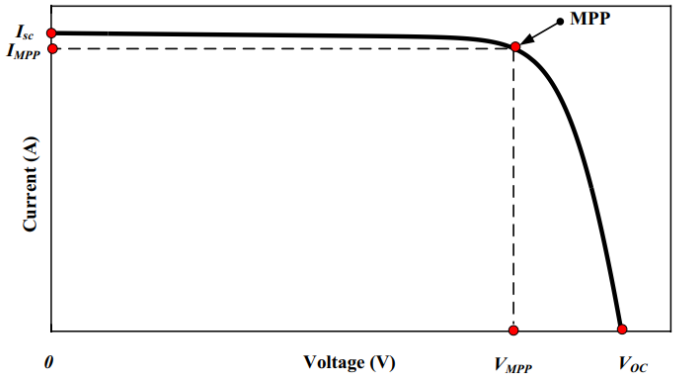

Figure 2: VI plot for the PV module (Hamdan, et al., 2019)

The photo current depends on the temperature of the solar cell and the solar radiation, which is governed by the following equation (Dey, et al., 2016).

$$I_{pv} = H * (I_{sc}(T_{ref}) + K_1(T_{cell} - T_{ref})) \quad (3)$$

Where,
H: The solar insolation in KW/m^2
$I_{sc}(T_{ref})$: The short circuit current at the standard radiation which is 100 W/m^2 and reference temperature, which is 25 °C
K_1: The temperature coefficient of the solar cell's short circuit current
T_{ref}: The solar cell reference temperature

The reverse saturation current of the diode is only a function of the cell temperature, which is governed by the following equations.

$$I_o = I_{rs}\left(\frac{T_{cell}}{T_{ref}}\right)^3 \exp\left(\frac{qE_G\left(\frac{1}{T_{ref}} - \frac{1}{T_{cell}}\right)}{KA}\right) \quad (4)$$

$$I_{rs} = \frac{I_{sc}(T_{ref})}{\left(\exp\left(\frac{qV_{oc}}{kAT_{ref}}\right) - 1\right)} \quad (5)$$

2.2 The mathematical model of the wind turbine

The main aim of the wind turbine is to utilise the kinetic energy of the wind and convert it into electricity by spinning the turbine blades, which are connected to an electric generator. The kinetic energy and power of the moving parts of the wind can be calculated using the equations below (Asghar & Liu, 2018).

$$E = 0.5 * m * v^2 \quad (6)$$

$$P = 0.5 * \dot{m} * v^2 \quad (7)$$

Air is the moving fluid that works on spinning the turbine blades so that the mass flow rate of the air will be replaced in terms of its speed, density and area. The power extracted by the wind turbine will be.

$$P = 0.5 * \rho * A * v^3 * C_p \quad (8)$$

Where C_p is the performance coefficient, and it depends on the tip speed ratio (λ), which is the ratio between the tip speed of the turbine blade and the wind speed (Posa, 2020). The best condition is when the C_p is maximum, which is achieved at the optimum value for λ, as shown in Figure 3.

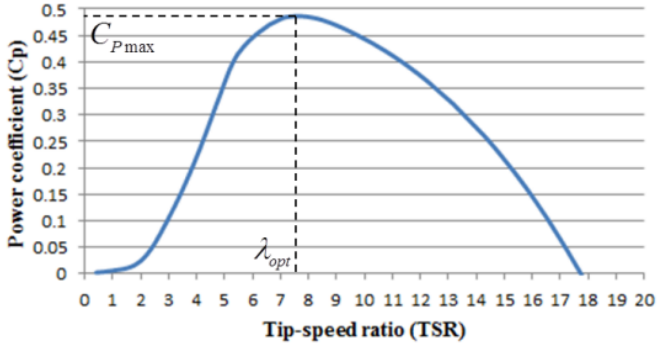

Figure 3: Relation between tip speed ratio and performance coefficient (Asghar & Liu, 2018)

The wind power curve as shown in Figure 4 presents four parameters associated with the wind turbine operation. If the wind speed is less than the cut-in speed, there will be no power production because the kinetic energy of the wind cannot overcome the inertia of the blades (Gloe, et al., 2019). The wind turbine starts producing power when the wind speed exceeds the cut-in speed. When the wind speed reaches the rated speed, the wind turbines will produce maximum power and the curve will remain constant at this speed. The wind turbine will stop producing power when

the wind speed exceeds the cut-out speed because the speed will be very high and may cause damages for the turbine (Pagnini, et al., 2015).

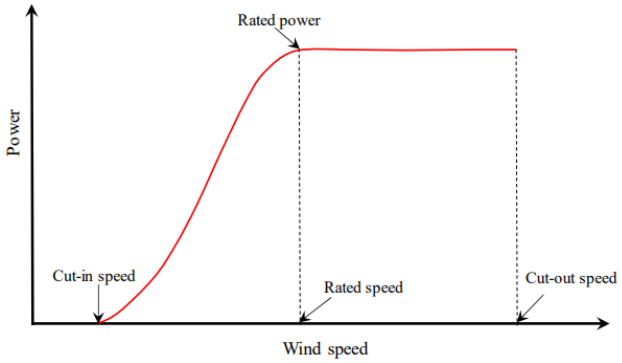

Figure 4: Wind power curve (Rehman, et al., 2018)

3. Methodology

3.1 HOMER pro software description

HOMER (Hybrid Optimisation Model for Electrical Renewables) software is the selected simulation software, which has a wide range of standards for optimising the proposed design of a renewable hybrid system. The optimisation feature of HOMER pro ensure that is software is appropriate for the discussion in this work. The availability of different designs of hybrid power that HOMER Pro software provides a variety of configurations to consider the load demand of energy. Different components are available to construct the solar-wind hybrid energy system, such as PV cells, wind turbines, storage units, power electronics converters, etc.

3.2 HOMER hybrid system design

The simulation of the proposed design can be illustrated by providing the proper load profile that will be the target demand. The target load is the agriculture community as shown in Figure 5, where the suggested load involves the consumed power by the residential activities and the rated power for the water pumps that are used for the agriculture activities. The system connections consider the nature of the output power of both the wind turbine and the PV panel. Wind turbine and PV panel in the proposed design are considered to be the generator of electrical power. A DC/AC converter takes care of converting the generated power of PV from DC to AC.

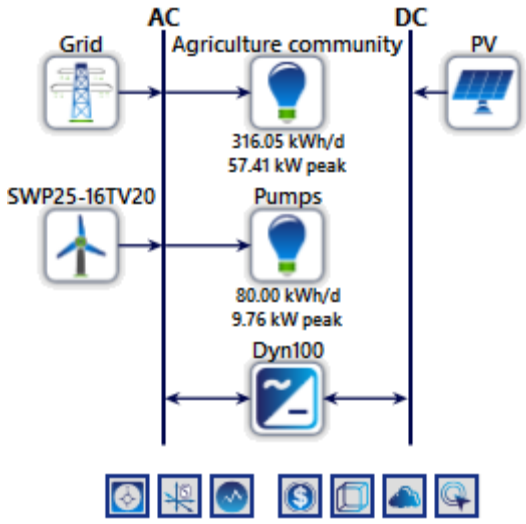

Figure 5: PV-wind hybrid system

3.2.1 Photovoltaic energy conversion systems and Power converter

A photovoltaic system, also PV system or solar power system, is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system.

In this design, the generic flat PV with a 1 kW capacity, a $3000 capital cost, a $2250 replacement cost, and an annual O&M cost of $10 was utilised. Regarding the number of PV units, the home pro software optimises the number in accordance with the other renewable energy sources and the demand. The 100 kW Dynapower SPS converter was chosen based on the community's peak power demand and pump load. This converter has a capital cost of $1,831.97, a replacement cost of $687.00, and an operation and maintenance cost of 10 $/year. (Saha, et al., 2022).

3.2.2 Wind turbines

Wind turbines are devices that convert the kinetic energy of the wind into electrical power. Wind turbines are classified by the orientation of their axes, the number of blades, and whether they are horizontal or vertical-axis machines. The three main types of wind turbines are: - Horizontal axis wind turbines (HAWT) - Vertical axis wind turbines (VAWT) - Hybrid systems (HAWT/VAWT).

According to the availability of different types of PV panels and wind turbine, specific characteristics are identified for the role of this work. For a wind turbine, these characteristics can be summarised in the following Table 1:

Table 1: The main characteristics of the wind turbine model

Hub Height	18 meters
Life Time (year)	20 years
Capital cost	$100,000.00
Replacement cost	$80,000.00
Operating and maintenance	$1200

The configuration of the system, which is shown in Figure 5, has been constructed based on a well-prepared methodology that was followed in order to cover the different activities of the agriculture community. This methodology can be summarised in Figure 6, in which the steps of work workflow were identified in a clear way.

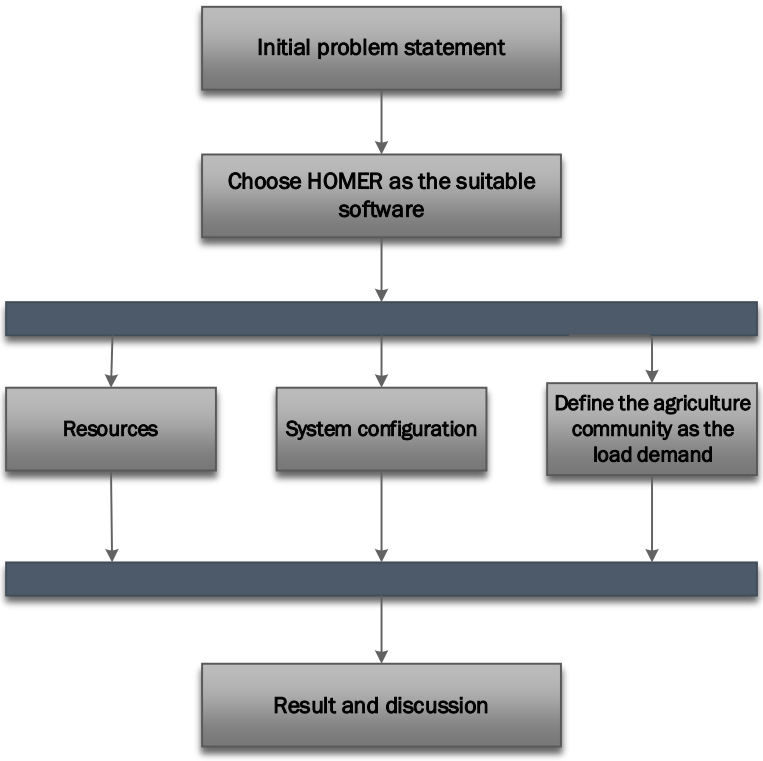

Figure 6: work flowchart

3.3 Location description

In order to get a wide range of information for the suitable design that can be employed in Jordan, three different locations were investigated in terms of the different factors that play a crucial role in the design of the suggested hybrid renewable system. These locations are Ruwaished, Zarqa and Al-Shoubak; these locations are distributed along Jordan from north to south. These three locations were chosen such that cover the different climate conditions and the various geography of Jordan. Daily radiation and daily temperature are the essential factors that have a significant effect on the solar system, where the amount of generated power basically depends on the radiation. On the other hand, the efficiency of PV solar panels is affected by the temperature. Figure 7 and Figure 8 display the daily radiation and daily temperature for these three locations over the year's months. As shown in Figure 7, Shoubak has the highest radiation compared to the other two locations in particular in summer, although the values of solar radiation are too close to each other. Discussing the temperature of these three locations, Figure 8 shows that Shoubak has the highest temperature at winter, while Ruwaished has the highest temperature at summer.

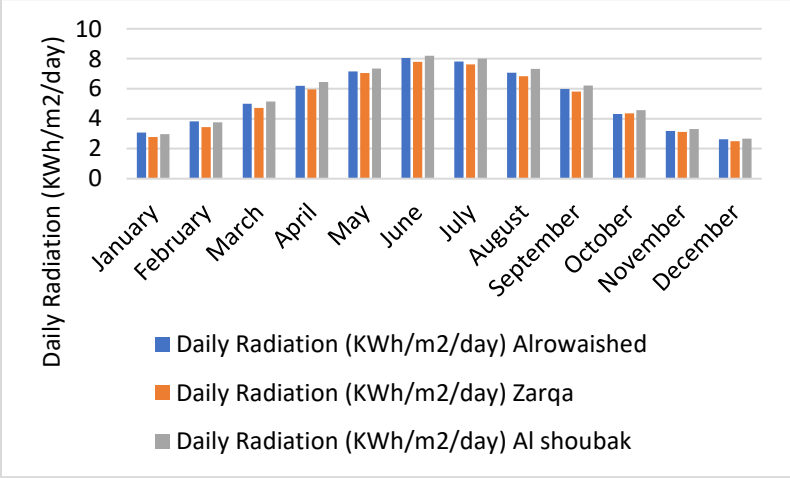

Figure 7: Daily radiation of three different locations in Jordan

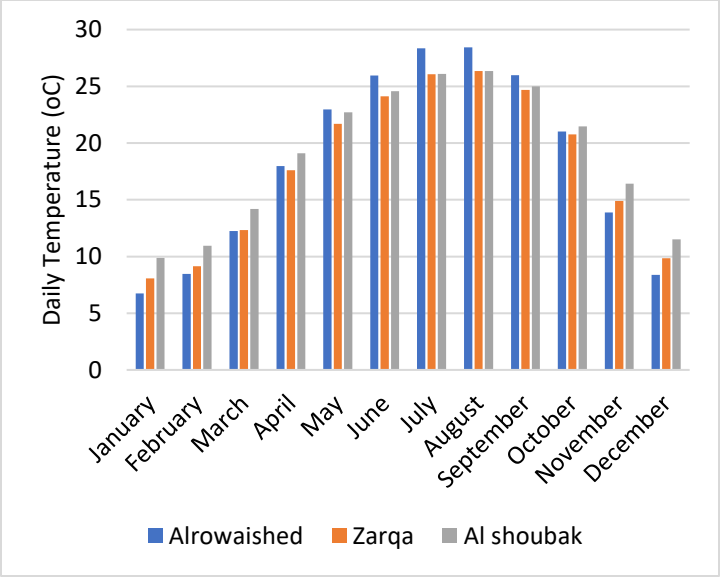

Figure 8: Daily temperature of three different locations in Jordan

Considering that the hybrid system involves a wind energy system, the wind speed at these three different locations should be investigated in order to optimise the output power of the wind energy system. Figure 9 shows the average wind speed over the year's months, in which Zara has the highest average speed of wind in the winter. In summer, the average wind speed for the three locations is approximately the same.

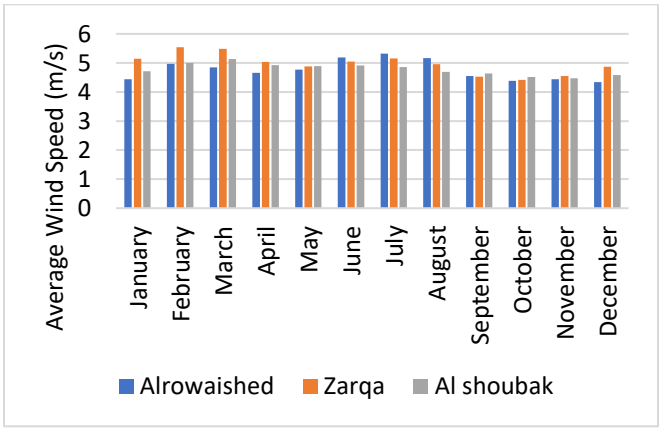

Figure 9: Average wind speed of different three locations in Jordan

3.4 Load and pump profile

The idea of modelling the agriculture community as an electrical load can be studied in an optimal way by considering the pumps and residential load separately. The same load was simulated in the three locations in order to make the comparison clearer and more reliable. Figure 10 introduce load

peak at different times in the year. This load referred to the general activities of the residential people which is the usual activities. The peak load has reached to its maximum value at summer as expected due to extensive use of conditions due to the increasing of temperature that occurs in summer.

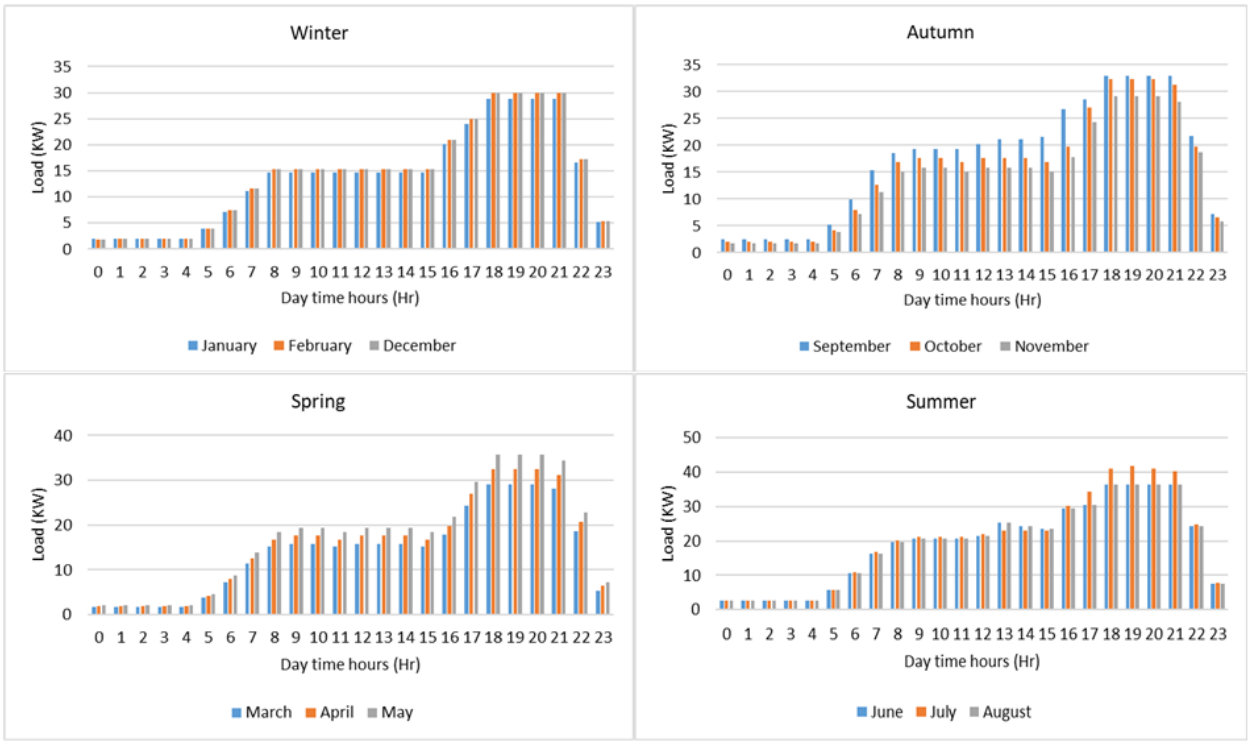

Figure 10:The load peak at the different seasons

The agriculture activities in the selected locations have been developed by employing significant tools in the irrigation process, in which the pumps are the central equipment in the irrigation system. According to Figure 11, the pumps load extends to more day's hours in mode 2, which is the summer season in which the plants under risk of dryness due to high temperatures. Mode 1 illustrates the case in winter, where the pumps run over a shorter period of time, so the peak load is extended for shorter period.

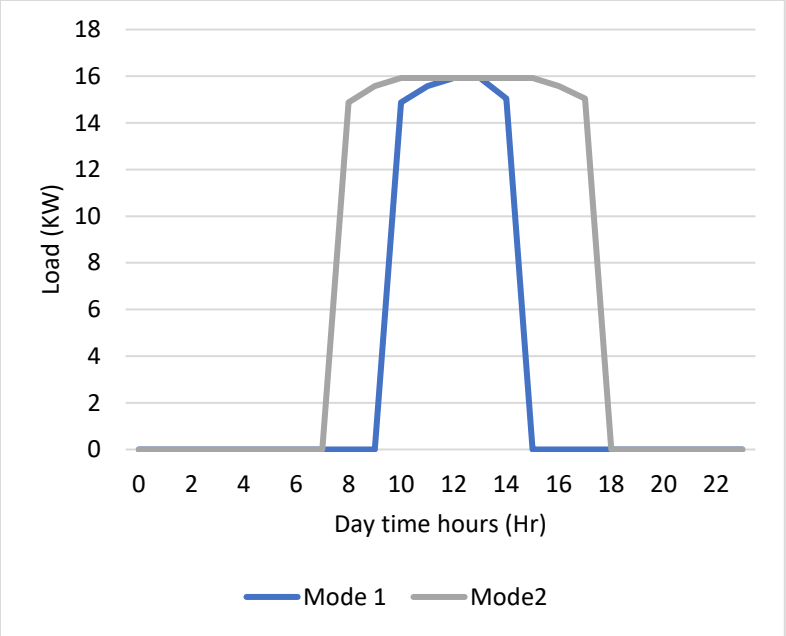

Figure 11:Pumps load at two different modes (mode 1: at winter, mode 2: at summer)

4. Results and discussion

4.1 Overview

Jordan is one of the countries that depends on importing crude oil to be able to use its products to generate electricity, and this contributes to harming the environment and exacerbating the problem of global warming. The Jordanian people also suffer from the high cost of electricity, transportation and generation, and the purchase price per kilowatt. Although Jordan is considered a water-poor country, it is considered an agricultural country due to the fertility of its soil and its suitability for agriculture, especially in the northern part of the kingdom. However, the high cost of electricity and water scarcity were the main two reasons for hindering agriculture in Jordan, despite the presence of the climate and conditions suitable for agriculture. All these challenges and limitations were the main reasons for resorting to and benefiting from renewable energy sources to generate electricity in addition to being environmentally friendly. These challenges were the impetus to intensify research and develop the current technologies related to electricity production in line with the environmental issues and preservation, so this study was carried out. The main idea of this study is to rely on solar radiation and wind speed by using the solar photovoltaic panels and wind turbines to generate electricity to cover the electrical load of a community consisting of 20

to 30 homes. For each community, there will be a farm consists of PV modules and wind turbines to generate the required electricity for the community. Three locations in the kingdom which are Zarqa, Shoubak and Ruwaished were selected to analyze the power output of the hybrid system. HOMER pro software was used to conduct the power and cost analysis taking into account that HOMER pro depends on the Net Present Cost (NPC) and the levelized cost of energy (LCOE) to optimize and analyze the power and cost.

The Net Present Cost (NPC) is the total cost of a project, including all costs incurred during its construction and operation, discounted to present value. The NPC of a wind and PV hybrid renewable energy system is the sum of the NPCs of its component parts: the wind turbines (WTs), the solar panels, the inverters, and the balance-of-system equipment. The levelized cost of energy (LCOE) is a measure of a power source which allows comparison of different methods of generating electricity. It is commonly used to compare different forms of generation on a consistent basis. (LCOE) is the NPC divided by the total energy output of the system over its lifetime.

4.2 The results of Zarqa city location

The results of HOMER's simulation are shown in Table 2. As a result of the optimization, three configurations were retained, and they were arranged in accordance with the NPC. The PV, WT, and Grid HERs configuration was selected as the optimal system for the agriculture community load profile. As shown in Figure 12, the proposed system generates 145,176 kWh/year, making it the best NPC with a renewable energy efficiency of 70.1% (17.7% PV, 52.8% WTs). The system consists of 23 PV panels and two wind turbines, which represent the idea of full HERs.

Table 2: Zarqa city simulation results

Configuration	*Production (KWh/yr)*	*NPC ($)*	*COE ($)*	*Grid Purchased (kWh)*	*Renewable fraction (%)*
PV + Wind + Grid	145176	578020.2	0.221	60519.98	70.0
Wind + Grid	217347	633359.5	0.173	65446.2	76.9
PV + Grid	215281	807874.3	0.279	67305.52	70

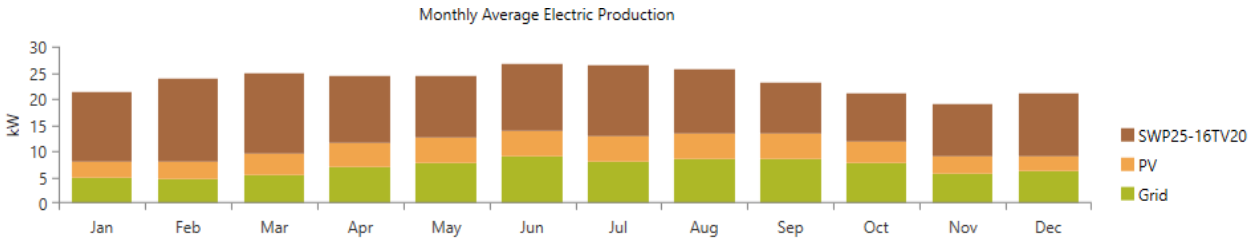

Figure 12: Monthly Average Electric Production for Zarqa location

The output of renewable resources, such as wind and solar, can be quite variable. This can pose a challenge to utilities that must maintain a certain level of power on the grid at all times. One way to address this challenge is to have a mix of resources that can provide power at different times of day. For example, wind speeds are often highest at night, while solar output is highest during the day. Another way to address the variability of renewable resources is to store energy when it is generated and then use it when needed. This can be done with batteries or by using excess power to pump water, but in this design, the energy gap is filled by the grid. As shown in Figure 13, the absence of solar radiation is compensated for by the presence of wind during the night.

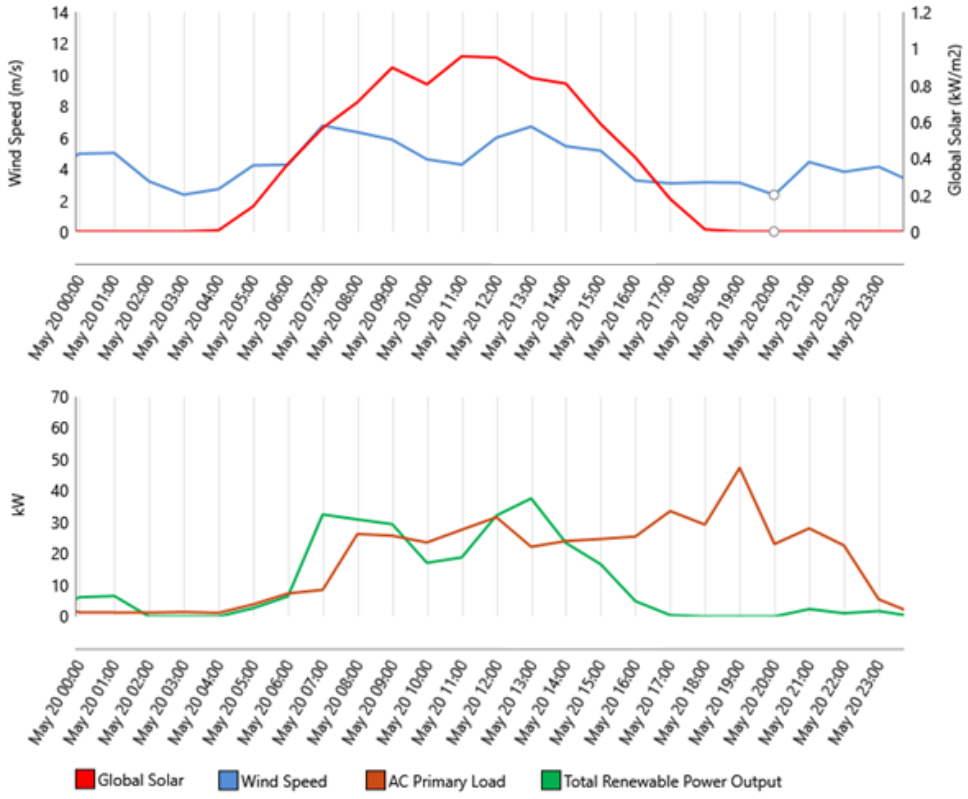

Figure 13: For the month of May, the interference between renewable resources (Wind speed and Global solar). Interference between renewable energy and load for the month of May.

The system is designed to reduce the need for grid electricity, but there are still times when it will be necessary to supplement renewable energy with power from the grid. This usually happens during the evening and nighttime hours when renewable energy sources such as wind and solar are not available. There are two main ways that the system can purchase grid electricity: 1. The system can purchase grid electricity when it is needed to supplement renewable energy. 2. The system can purchase grid electricity in advance of when it is needed, and then use that electricity as needed.

In order to meet the community's goal of reducing its carbon footprint, the system is designed to use 100% renewable energy when available. When renewable energy is not available between 16:00 and 23:00, the system purchases grid electricity. The system has a maximum capacity of 145.176 MW of pure renewable energy and is expected to save the community $29,505.32 in energy costs.

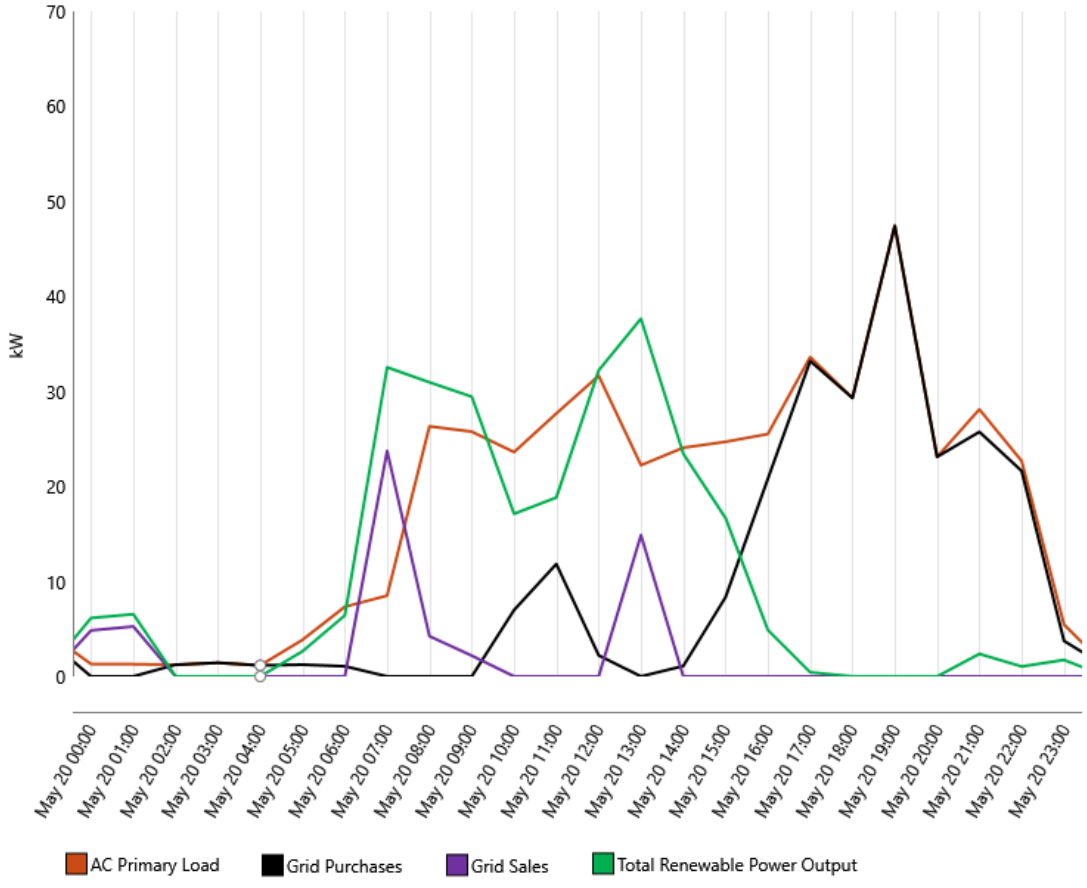

Figure 14: Interference between renewable energy production and the amount of electricity the system purchases and sells from the grid.

4.3 The results of the Shoubak city location

Considering the results that are described in Table 3, in which simulation results are described to discuss the generated power and the different types of cost such as NPC. In Table 3, three configurations were studied, the first configuration the hybrid model is enhanced by the grid to cover the total generated power. According to the NPC value, the first configuration is the optimal configuration for the agricultural community in Shoubak location, in which this configuration has the lowest value. Figure 15, the produced energy, which is 144152 kWh/year by the optimal system, in detail according to months of the year. About 70.9% of the generated energy is renewable energy (22.2% PV, 48.7% WTs). This hybrid system is constructed by 27 PV panels and two wind turbines, compared to the system, which involves only PV panels, which consists of about 100 panels.

Table 3: Shoubak city simulation results

Configuration	*Production (KWh/yr)*	*NPC ($)*	*Operating cost ($/yr)*	*Initial capital ($)*	*Grid Purchased (kWh)*	*Grid Sold (kWh)*
PV + Wind + Grid	144152	597162.4	22252.88	309488.1	59115.93	54541.64
Wind + Grid	197917	670171.3	20898.93	400000	68910.98	122270.5
PV + Grid	170602	764211.1	25808.77	430567.8	68729.3	85769.52

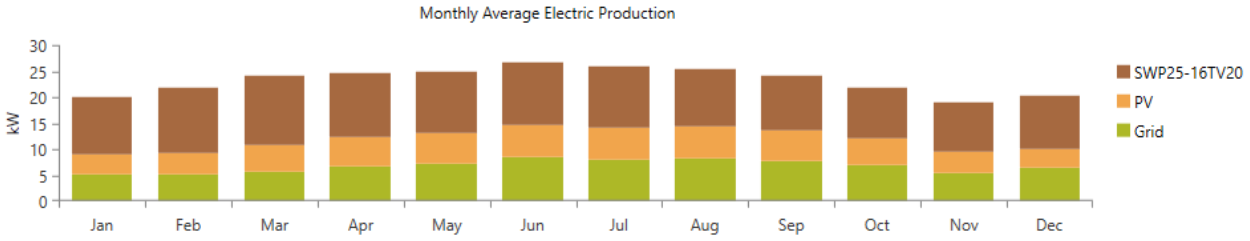

Figure 15: Monthly Average Electric Production for the Shoubak location

In the reason of different factors that are mentioned before, the generated power by the wind system and the solar system varies at different times of the year. Figure 16 shows the variations in the global radiation and wind speed at different times in May. Also, the primary load and renewable power output were also displayed to give a good view of the proposed system.

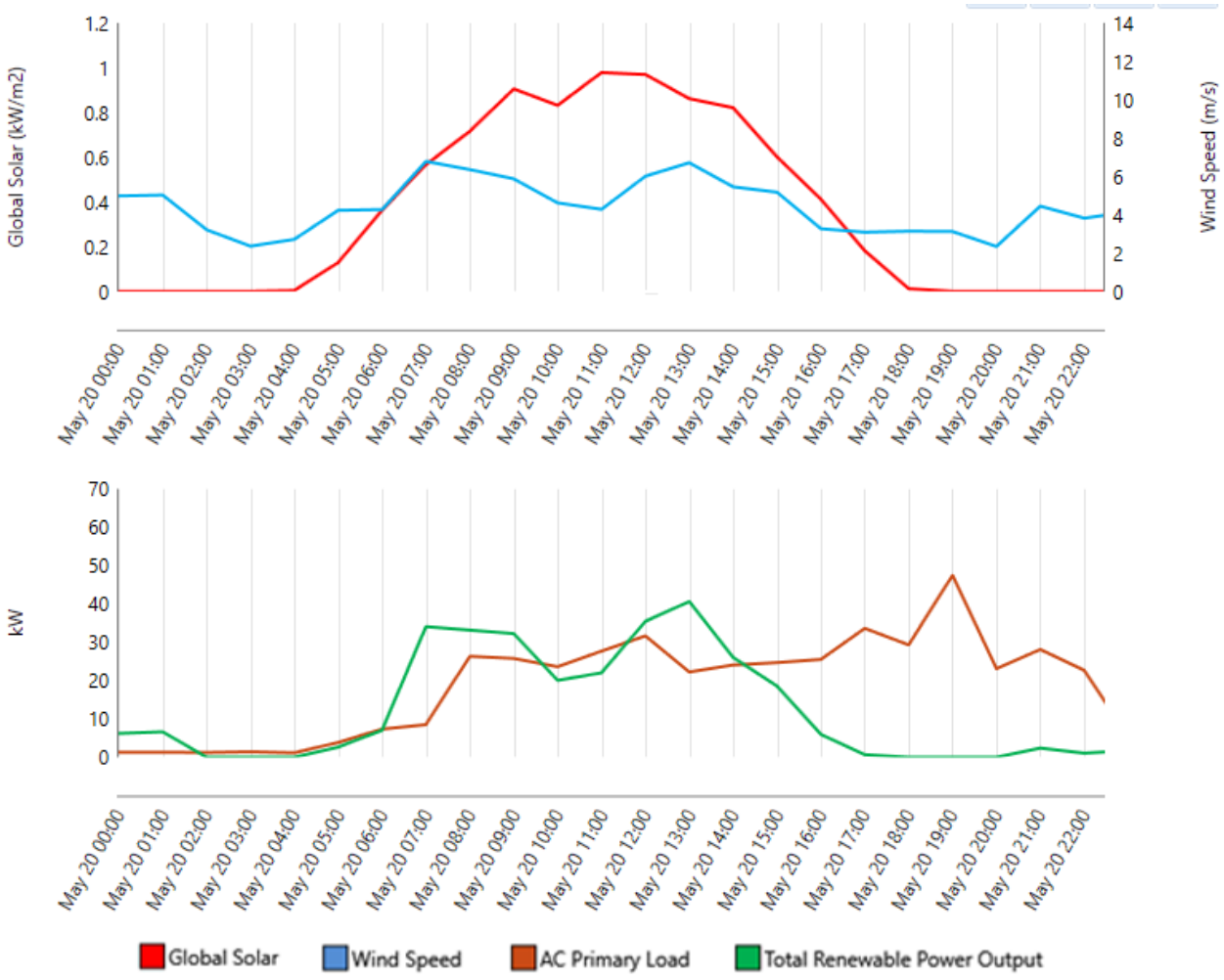

Figure 16: For the month of May, the interference between renewable resources (Wind speed and Global solar). Interference between renewable energy and load for the month of May

The purpose of the hybrid system that was developed is to reduce the electricity that is consumed from the grid. However, the grid is still needed to support the hybrid system to cover the demand of the agriculture community. According to Figure 17, the renewable energy is not available between 17:00 and 20:00.

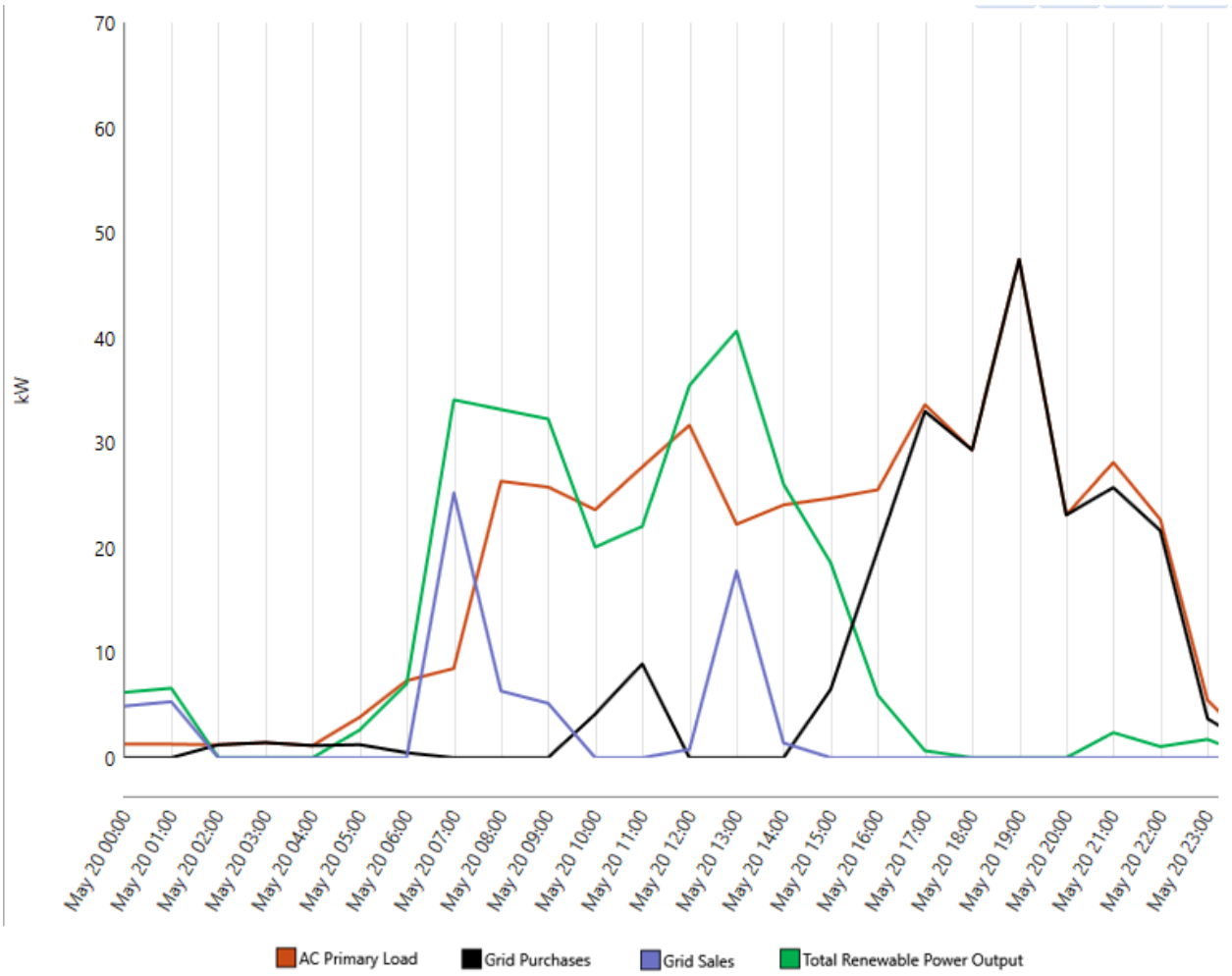

Figure 17:Interference between renewable energy production and the amount of electricity the system purchases and sells from the grid

4.4 The results of the Ruwaished city location

Table 4: Ruwaished city simulation results

Configuration	*Production*	*NPC ($)*	*Operating cost ($/yr)*	*Initial capital ($)*	*Grid Purchased (kWh)*	*Grid Sold (kWh)*
PV + Wind + Grid	144019	600454.3	22374.51	311207.4	59311.44	53709
Wind + Grid	195761	673358.6	21145.48	400000	69029.61	120233.4
PV + Grid	190297	764666.1	24634.46	446203.7	68952.09	85619.98

h

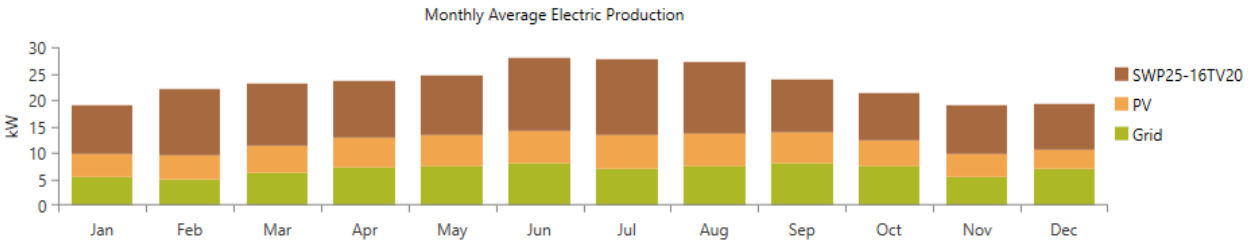

Figure 18: Monthly average electric production

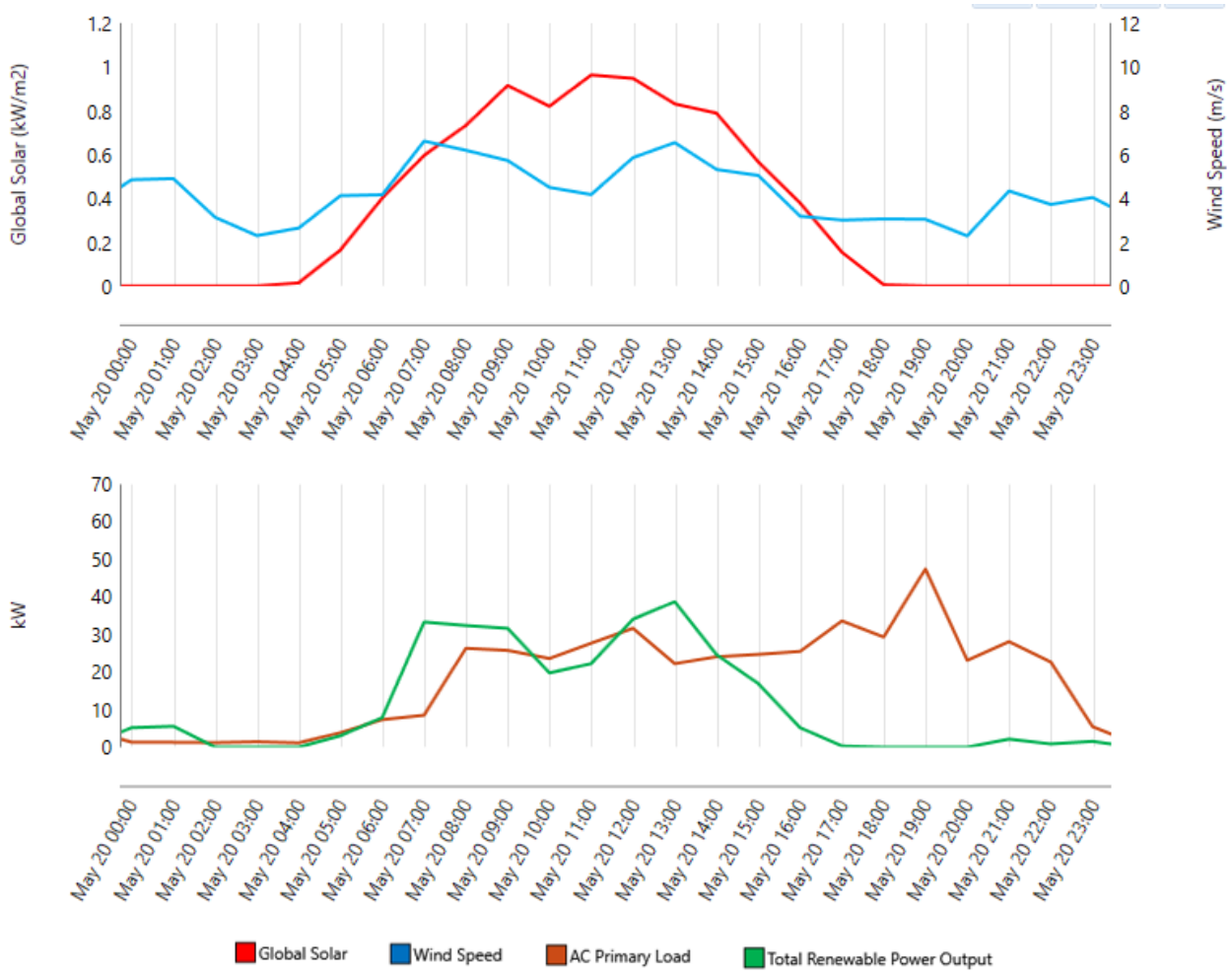

FIGURE 19: Interference between the monthly renewable energy production and the amount of electricity the system purchases and sells from the grid

5. Overall discussion

Solar and wind power are two of the most promising renewable energy sources, as these sources are both abundant, environmentally friendly, and relatively easy to exploit these sources. However,

solar and wind power have one major disadvantage, where the process of produce occurs that when the sun is shining or the wind is blowing. This makes them difficult to integrate into existing power grids, which are designed around constant, predictable sources of generation such as coal-fired power plants. One of the main solutions to this problem is to implement energy storage. By storing surplus electricity generated by solar and wind farms in an energy storage system (ESS), it becomes possible to even out the variability of renewable generation and provide a more reliable source of power. The Homer Pro software is a battery management system that allows energy surpluses from solar panels or wind turbines to be stored in batteries and then utilised when needed. The Homer Pro software is compatible with all battery types, including both lead-acid and lithium-ion batteries.

6. Conclusion

Renewable energy is a key driver of sustainable development and climate change mitigation. It offers an opportunity to create green jobs, reduce air pollution and develop a more diversified energy mix. Jordan has great potential for renewable energy, particularly solar and wind. The country has one of the highest levels of solar insolation in the world and strong winds in some areas. Renewables currently account for around 2% of Jordan's total energy mix. The government has set a target to increase this to 10% by 2025. Jordan's renewable energy sector is young but growing rapidly. There are several large-scale solar and wind projects in the pipeline, as well as a number of smaller initiatives. The government is supportive of renewable energy development, and there are a number of financial incentives in place to encourage investment. The use of renewable energy can help Jordan sustainably meet its energy needs, while also creating jobs, reducing air pollution and contributing to climate change mitigation.

Homer Pro is a hybrid energy system design software that can be used to design a system that utilises both renewable and non-renewable energy sources. This study will use Homer Pro to design a hybrid energy system for three different agricultural locations in Jordan. The objective of this study is to provide a detailed analysis of the technical and economic feasibility of using Homer Pro to design a hybrid energy system for agriculture in Jordan. In this study, three farm locations were chosen: the first one is located in Zarqa Governorate, the second one is located in Ma'an Governorate, and the third one is located in Mafraq Governorate. The following technical and

economic parameters were used for this study: solar insolation, wind speed, landscape, farm size, energy demand, demand profile, energy price, investment cost, operation and maintenance cost, and fuel cost. After designing the hybrid energy system for each farm location, the total cost of energy (COE) was calculated. The results showed that the hybrid energy system is technically and economically feasible for agriculture in Jordan. Also, the study of hybrid renewable energy (HRE) systems can provide many benefits for Jordan's agricultural sector. The use of HRE systems in agriculture can help to reduce the reliance on fossil fuels, lower emissions, and improve the overall efficiency of farm operations. Additionally, HRE systems can help to stabilize the electric grid and provide a reliable source of power during times of peak demand. Given the intermittent nature of renewable energy sources, the objective of this research is to examine how energy profile gaps can be filled. The intermittency of renewable energy resources like solar and wind power can create challenges for electric utilities when it comes to maintaining a reliable and affordable power grid. In order to address these challenges, utilities must have a clear understanding of the potential sources of interference between renewable energy production and grid purchases and sales. Some of the most common sources of interference include net metering policies that do not take into account the variability of renewable energy resources. The second source is the lack of coordination between utility dispatch centres and renewable energy producers. In addition, inadequate integration of renewable energy resources into existing grid operations and planning processes. Finally, the lack of transparency in wholesale electricity markets regarding the presence of intermittent renewable resources.

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